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CARBON DIOXIDE EMISSION FROM SOILS FOLLOWING DIRECT SEEDING

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Introduction

Soil organic matter (SOM) is important to maintain soil fertility and productivity. A management system that increases SOM will improve soil quality, and thus has the potential to increase agricultural productivity. In addition, such a system offers environmental benefits, including reduced soil erosion and improved water quality. Management systems may produce changes in agroecosystem SOM levels by altering carbon inputs and outputs.

Plowing decreases soil organic matter by allowing oxygen into the soil and increasing residue contact with the soil. The oxygen is used by aerobic, heterotrophic soil microorganisms to mineralize the carbon-containing compounds in the residue to carbon dioxide (CO_2). Carbon dioxide is a gas, which is eventually lost to the atmosphere. In microbial terms, it is essentially an inert compound. It cannot be used as a source of energy by soil microorganisms because it is too oxidized; hence it does not contribute to the formation of SOM. By measuring the amount of CO_2 released from soil following tillage, it was shown that plowed fields at the Columbia Plateau Conservation Research Center near Pendleton lost nearly 305 lb more carbon per acre than fields that were not plowed. The carbon loss is equivalent to approximately 759 lb residue/acre (Albrecht et al., 1998). In addition, when the residue is turned over by plowing, it comes into increased contact with the soil and the microorganisms in the soil. Buried residue offers a more stable habitat for the soil microorganisms, in terms of moisture and temperature, than residue left on the soil surface.

The awareness of the problems created by the production of greenhouse gases, primarily CO_2, methane, and nitrous oxide, has created the need to develop strategies to reduce the emission of or contain these radiatively active gases. Sequestering carbon in agricultural soils by increasing the SOM content through the management of crop and grazing lands is one possible method to reduce CO_2 in the atmosphere. Any management system that will provide for this sequestering of carbon in the soil will also help reduce problems caused by increasing CO_2 concentration in the atmosphere.

Plowing has a detrimental effect on SOM (Albrecht et al., 1998; Reicosky, 1998). Utilizing a management system that includes direct seeding into residue will eliminate or reduce plowing and should benefit SOM. However, little is known about how reduced tillage and direct seeding operations may effect CO_2 release from the soil or how they may impact SOM. This study was begun to evaluate the effects of direct seeding on CO_2 emissions to the atmosphere and to compare two types of direct seed drills.

Materials and Methods

The experiments were conducted on the Buchanan Farm, on Lewis Peak Road, north of Dixie, Washington. Direct seeding treatments covered a range of depths, fertilizer additions, and soil disturbance. The five seeding regimes are shown in Table 1.

Table 1. Direct seeding regimes, Buchanan Farm near Dixie, WA, Sept. 1997.

Number	Drill	Fertilizer (lb/acre)	Disturbance
1	Yielder	100 N (anhydrous) + starter[1]	about 5 in deep[2]
2	Flexi-Coil	100 N urea + starter	about 2–2.5 in below seed
3	Flexi-Coil	Starter only	about 2–2.5 in below seed
4	Flexi-Coil	Starter only	about 1–1.5 in below seed
5	Flexi-Coil	200 N urea + starter + other[3]	about 2–2.5 in below seed

[1] Starter fertilizer for the Yielder was 16 lb/acre N, 20 lb/acre P_2O_5, 22 lb/acre K and 14 lb/acre S.
[2] Soil disturbance generated by the Yielder was to the side of the seed row.
[3] Fertilizer for treatment 5 included 44 lb/acre N, 7.6 lb/acre P_2O_5, 8.3 lb/acre K, and 5.3 lb/acre S.

The plots were seeded on 11 September using the Flexi-Coil 5000 air seeder with Stealth hoe-type openers and on 12 September 1997 using the Yielder with a 5–15 in pair row configuration and anhydrous ammonia deep-banded between 5-in rows. Winter wheat seeds, variety Madsen, were drilled into standing chickpea (garbanzo bean) residue at 120 lb/acre (19 seeds/ft^2). The plots are 16 ft × 130 ft with six replications and arranged in completely randomized blocks.

The CO_2 flux, or loss, from the drilled areas was measured using a Li-Cor soil-respiration chamber connected to a portable infrared gas analyzer. The soil-respiration chamber has a volume of 58.7 in^3 and covers an area of 11.1 in^2. It includes soil and air temperature thermocouple probes, a relative humidity sensor, and a pressure release port for pressure equilibration. The gas flux, or flow, from the soil surface is expressed in concentration of gas per unit area per unit time. Once the drill passed over the soil, the chamber was placed on the soil surface. The analyzer was programmed to calculate a flux rate after a 10 ppm increase in CO_2. To begin the measurements, the CO_2 concentration inside the chamber was reduced to about 20 ppm lower than ambient by diverting the gas flow through soda lime. For each determination, the flux rate was measured four times, two times with the CO_2 concentration inside the chamber at less than atmospheric concentration (ca. 350 ppm) and two times when the CO_2 concentration was greater than atmospheric levels. The later measurements were made as the CO_2 in the chamber was allowed to increase over ambient. The average of the four measurements was calculated for each determination. In addition, CO_2 flux from nonseeded areas (controls) was also taken. Data analysis (ANOVA) was done using CoHort Software with CO_2, soil temperature, and soil moisture as variables.

Results and Discussion

There was a noticeable crust on the soil (about 0.125 in) at the time of seeding. Placement of the CO_2 collection chamber disrupted the crust and allowed trapped gases to escape. Immediate CO_2 flux from the soil, following the placement of the chamber, was quite rapid; however, it decreased rather quickly (Figure 1). After 6 to 10 min the CO_2 flux from the soil remained at a relatively steady state. Once the CO_2 flux rate stabilized, the increase of CO_2 in the chamber was linear with time (Figure 2).

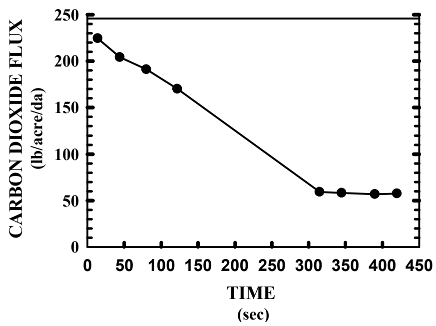

Figure 1. Example of CO_2 flux immediately after a minor disturbance caused by placement of the chamber. Any soil disturbance causes a temporary release of trapped CO_2.

Seeding by the Flexi-Coil drill was completed on 11 September. The CO_2 collection chamber was placed in the depression made by a packer wheel immediately after the drill passed over the area. The CO_2 flux determination began about one to two minutes after the seed was drilled into the soil. Time constraints determined that not all replicate plots could be measured in one day; hence, only four of the six replications were usually measured. Measurements were made from 11:30 to

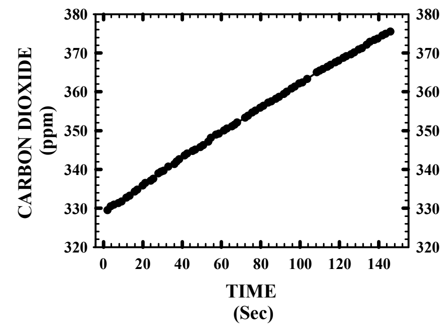

Figure 2. Gradual increase in CO2 in a chamber placed over the soil. The increase is due to the normal microbial respiration in the soil.

15:10 Pacific Standard Time. The average time required for the flux determination was 221 sec. Soil temperatures at 4 in ranged from 69.1 to 73.6 ºF (average was 70.7 ºF). The temperature inside the chamber remained within 0.2 ºF during the measurement. The soil temperatures for treatments 4 and 5 were significantly different, although only 1.4 ºF apart. The soil in this field was friable following the garbanzo beans and relatively dry. Soil moisture in the top 2 in was only 1.7 percent, increasing to only 5.2 percent at 10 in. Treatment 1 had significantly more soil moisture than the other treatments, 5.6 percent over all depths compared to 3.7 percent found in all other treatments. The flux rates ranged from a low of 38.2 lb CO_2/acre/da to a high of 46.7 lb CO_2/acre/da on 11 September (Figure 3). There was variability in the CO_2 flux determinations; however, none of the rates was statistically different. This suggests that the CO_2 flux rates caused by the Flexi-Coil drill were similar, regardless of depth of seed or fertilizer placement. In addition, the rates following a drill pass were similar to a

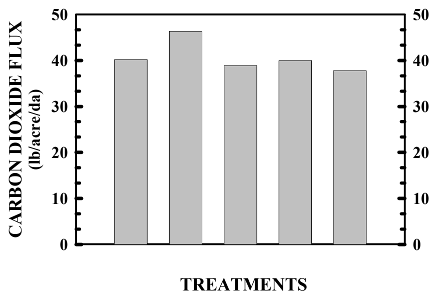

Figure 3. Carbon dioxide flux from fields that were direct seeded on 11 Sept. 1997. Buchanan Farm, on Lewis Peak Road, near Dixie, WA. Numbers on the X–axis correspond to treatments listed in Table 1; C is the control (nonseeded area).

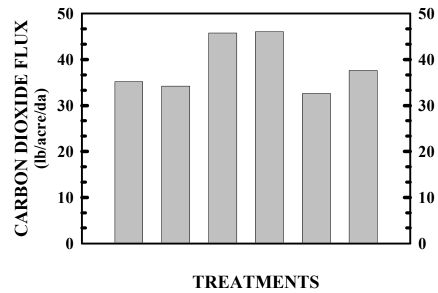

Figure 4. Carbon dioxide flux from fields that were direct seeded on 15 Sept. 1997. Buchanan Farm, on Lewis Peak Road, near Dixie, WA. Numbers on the X–axis correspond to treatments listed in Table 1; C is the control.

nonseeded control provided the crust was disturbed before the measurement. Measurement of CO_2 flux from a nonseeded area without prior disruption of the crust could generate rates as great as 71.7 lb CO_2/acre/da. There was little indication that the drill was incorporating a substantial amount of the residue into the soil.

Seeding by the Yielder drill was completed on 12 September. However, CO_2 flux measurements were not made until the morning of 15 September. Carbon dioxide flux measurements were made from 10:50 until 12:35 PST. Soil temperatures were cooler than on the 11th, ranging from 59.2 to 59.6 ºF with no significant differences among treatments. Soil moisture was not determined at this time. Again, the CO_2 flux rates were variable, ranging from slightly less than 33.6 lb. CO_2 per acre per day to a high of almost 46 lb CO_2 per acre per day (Figure 4). The flux rates were slightly less than those measured on 11 September; these rates are consistent with the cooler soil temperatures on 15 September. Analysis of the rates again showed that they were all statistically similar, including the nonseeded controls.

Carbon dioxide flux measurements were next taken on 8 October 1997 (Figure 5). Soil temperatures at 4 in were greatly reduced from previous determinations, ranging from 47.1 to 48.1 ºF, but were not significantly different among treatments. Soil moisture had increased after some

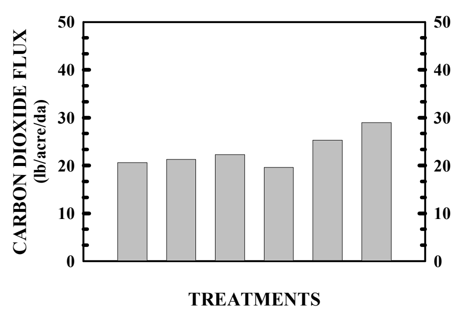

Figure 5. Carbon dioxide flux from fields that were direct seeded on 8 Oct. 1997. Buchanan Farm, on Lewis Peak Road, near Dixie, WA. Numbers on the X–axis correspond to treatments listed in Table 1; C is the control.

precipitation in the area (amount not determined) and was 15.2 percent at 4 in, declining to 11.3 percent at 8 in. There were no significant differences in soil moisture among treatments. Carbon dioxide flux rates were again variable; ranging from lows near 20 lb CO_2/acre/da to a high rate of about 30 lb CO_2/acre/da. Although there was a difference in rates of about 10 lb CO_2/acre/da between the high and low rate, none of the treatments was statistically different. The decrease in flux rate from previous measurements corresponds to the reduction in soil temperature.

Overall, the soil disruption, as determined by CO_2 flux rate, by the two drills was very similar. In addition, the soil disruption caused by different settings of the Flexi-Coil drill had no influence on the flux of CO_2 from this soil. It is probable that soil disruption, and subsequent CO_2 flux from the soil by direct seeding operations, will be minimal regardless of the type of drill used.

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